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TOWARDS AN UNDERSTANDING OF THE INTERACTION OF HAIR WITH THE DEPOSITIONAL ENVIRONMENT

Andrew S. Wilson[*], *Ronald A. Dixon*[**], *Howell G.M. Edwards*[***],
Dennis W. Farwell[***], Robert C. Janaway[*], A. Mark Pollard[*], Desmond J. Tobin[**]

[*]University of Bradford, Department of Archaeological Sciences, West Yorkshire BD7 1DP, Bradford, United Kingdom. E-mail: a.s.wilson2@bradford.ac.uk.
[**]University of Bradford, Department of Biomedical Sciences, West Yorkshire BD7 1DP, Bradford, United Kingdom.
[***]University of Bradford, Department of Chemical and Forensic Sciences, West Yorkshire BD7 1DP, Bradford, United Kingdom.

There is developing interest in the analytical use of human hair from archaeological contexts in key research areas such as DNA, trace elemental and isotopic analyses. Other human tissues, especially bone, that have been used for trace element, isotopic and DNA analyses have had extensive study concerning their diagenesis, but this has not been done for hair. Consideration must be given to the complex interaction of hair with its buried environment, thereby laying a firm basis for the use of hair in future research. Since human hair is known to survive under a diverse range of environmental conditions, a pilot study has investigated the basic processes of hair degradation, using samples from different climatic zones and burial types. Variation in the degree of preservation of archaeological hair was characterized by light microscopy, electron microscopy, and FT-Raman spectroscopy, relating morphological change of the surface and internal structure of hair to its biochemical integrity. The results demonstrate a breakdown of cortical cell boundaries and disruption of the cuticular layering, coupled with infiltration of material from the burial matrix that suggests a progressive loss of cohesion that is in part due to microbiological activity. Medullated hair is shown to be more susceptible to physical breakdown by providing two routes for microbial and environmental attack. At the molecular level the proteinaceous component undergoes alteration, and the S-S cystine linkages, responsible for the strength and resilience of hair in living individuals, are lost.

Key words: Scalp hair, degradation, contamination, microbial attack, TEM, FT-Raman Spectroscopy

Existe un gran interés en el uso analítico del pelo humano de contextos arqueológicos en áreas claves de investigación como los análisis de ADN, elementos traza e isótopos. Otros tejidos humanos, especialmente el hueso, que han sido usados para los análisis de ADN, elementos químicos e isótopos, han sido estudiados en relación a su diagénesis, pero esto no se ha realizado en pelo. Es necesario considerar la compleja interacción entre el pelo y el ambiente del entierro, creando así una base firme para el uso de éste en futuras investigaciones. A causa de que el pelo humano sobrevive bajo un rango diverso de condiciones ambientales, un estudio piloto ha investigado los procesos básicos de la degradación del pelo usando muestras de distintas zonas climáticas y tipos diferentes de entierros. La variación en el grado de preservación del pelo arqueológico fue caracterizada por microscopía de luz, microscopía de scanner electrónico y espectroscopía FT-Raman, relacionando el cambio morfológico de la superficie y la estructura interna con su integridad bioquímica. Los resultados demuestran una desintegración de los bordes de células corticales y la ruptura de las capas cuticulares, junto a la infiltración de materia de la matriz del entierro, que sugiere una pérdida progresiva de cohesión que se debe parcialmente a actividad microbiológica. El pelo medulado demuestra ser más susceptible a desintegración física dado que provee dos rutas para el ataque microbial y ambiental. Al nivel molecular, el

componente proteico pasa por alteración, y se pierden las conexiones de S-S cystine que son responsables de la fuerza y elasticidad del pelo en individuos vivos.

Palabras claves: *Cuero cabelludo, degradación, contaminación, microorganismos, espectroscopía FT Raman.*

Despite the early work by Trotter (Trotter 1943) who examined the hair of mummies from the Paracas Peninsula, Brothwell and Spearman (Brothwell 1963) were the first to examine hair from a range of archaeological environments. In recent years a renewed interest in archaeological hair has been fueled by advances in analytical techniques, allowing reconstruction of diet (Pain 1998), analysis of drug use, genetics (Bonnichsen 1996) etc. Yet the degree of preservation of ancient hair samples has not been subject to the same scrutiny as for archaeological bone. Already several investigations using hair of variable con

dition have produced results inconsistent with other types of archaeological evidence (Wilson submitted-a).

Hair survives in diverse archaeological environments, yet it is not found universally. The fact that hair degrades means that the complex interaction of hair with its depositional environment must be considered - thereby laying a firm basis for the use of hair in future research. The systematic investigation of hair degradation is fundamental to all hair research (Cartmell personal communication). Readers are referred to Ryder (1973) for a basic introduction to hair morphology and structure.

At Bradford University we are engaged in a multidisciplinary study examining variation in sample condition from diverse archaeological, forensic and museum environments. A pilot project examined human terminal scalp hair from 13 disparate contexts (Table 1). The degree of preservation of each sample was characterized by light microscopy, electron microscopy and FT-Raman spectroscopy - relating morphological change of the surface and internal structure of hair to its biochemical integrity.

Table 1 - Sample origins

Sample	Site	Environment	Sex	Age	Deposit date
H012	Sevenoaks, Kent, UK	lead coffin	?	?	17-1800s
H067	Kulubnarti, Sudan	cist	M	4	750-1500
H083	Nashville, Tennessee, USA	iron coffin	M	63	1867
H084	Illinois (forensic), USA	exposed forensic	M	52-65	1993
H088	Gloucester Landfill, Virginia, USA	wood coffin	F	20-24	1800s
H091	Colombian Exposition, AMNH, USA	museum storage	F	5	1893
H101	Wadi Faynan, Jordan	cist	?	?	c.600
H118	Newcastle Infirmary, Tyne and Wear, UK	wood coffin	M	45-55	1753-1845
H130	Pennsylvania (forensic), USA	exposed forensic	F	32	1964
H139	Geer site, Connecticut, USA	wood coffin	M	30-34	pre-1830
H159	Spitalfields, London, UK	lead coffin	?	?	17-1800s
H170	Spitalfields, London, UK	lead coffin	M	49	1794
H173	Ciutadella, Menorca	cave	?	?	c.500BC
H181	Kerma, Sudan	cist	F	?	2050-1750BC

Scanning electron microscopy was used to determine the external condition of individual fibres. Progressive changes to the cuticle along the hair shaft were consistent with weathering in life. More dramatic changes such as total loss of cuticle, separation of individual cortical cell bundles (fibrillation) and the presence of holes and erosion of the cortex characteristic of fungal tunneling highlighted the potentially aggressive nature of the depositional environment. However, adherent deposits such as clay or fungal hyphae frequently obscured the surface, so cross-sectional information was sought. Fibres were fixed and embedded prior to thin-sectioning. Transverse sections (tip, midshaft and root ends) were examined by light microscopy (0.5 (m thick sections) and transmission electron microscopy (100 nm thick sections).

Considerable variation in survival of internal morphology was noted at the inter-site level. Thin-sections confirmed that outwardly a fibre may appear normal, with the potential for the external cuticle to be retained, whilst the underlying cortex and medulla were disrupted. The tip and root ends of the fibres examined were more prone to degradative change than the midshaft, highlighting a crucial sampling issue.

Selective degradation -correspondant with the relative resistance of internal hair structures (Wilson 1999a) - resulted in differential loss of cell membrane complex [the lipid-protein-lipid boundary membrane between individual cortical cells] and progressive loss of cohesion between individual macrofibrils with an overall increase in porosity. At one extreme pigment granules and remnant exocuticle were all that survived with highly degraded samples. More recently, fibres recovered from experimental burial sites show similar morphological changes to the results of this pilot study (Wilson in preparation).

Extreme depositional environments may produce characteristic effects such as those noted with extreme desiccation. At the gross level, fibres from sample H101 were severely shrunken and embrittled. Thin sections showed a highly altered morphology with the only recognizable structures being shrunken pigment granules and cuspate cuticle.

Concomitant with the differential loss of parts of the cortex and the correspondent increase in porosity is the potential for influx of contaminants. Iron corrosion salts were distributed throughout the porous degraded root section of sample H083 from an iron coffin burial (Figure 1). FT-Raman spectroscopy provided confirmation that deposition of exogenous contaminants is particularly influenced by burial mode. The presence of carbonates in three samples [H159, H170, H173] relates to their depositional environments. Two came from lead-lined coffins and one came from a limestone cave. FT-Raman microscopy of fibre cross-sections confirmed that these were not simply surface deposits.

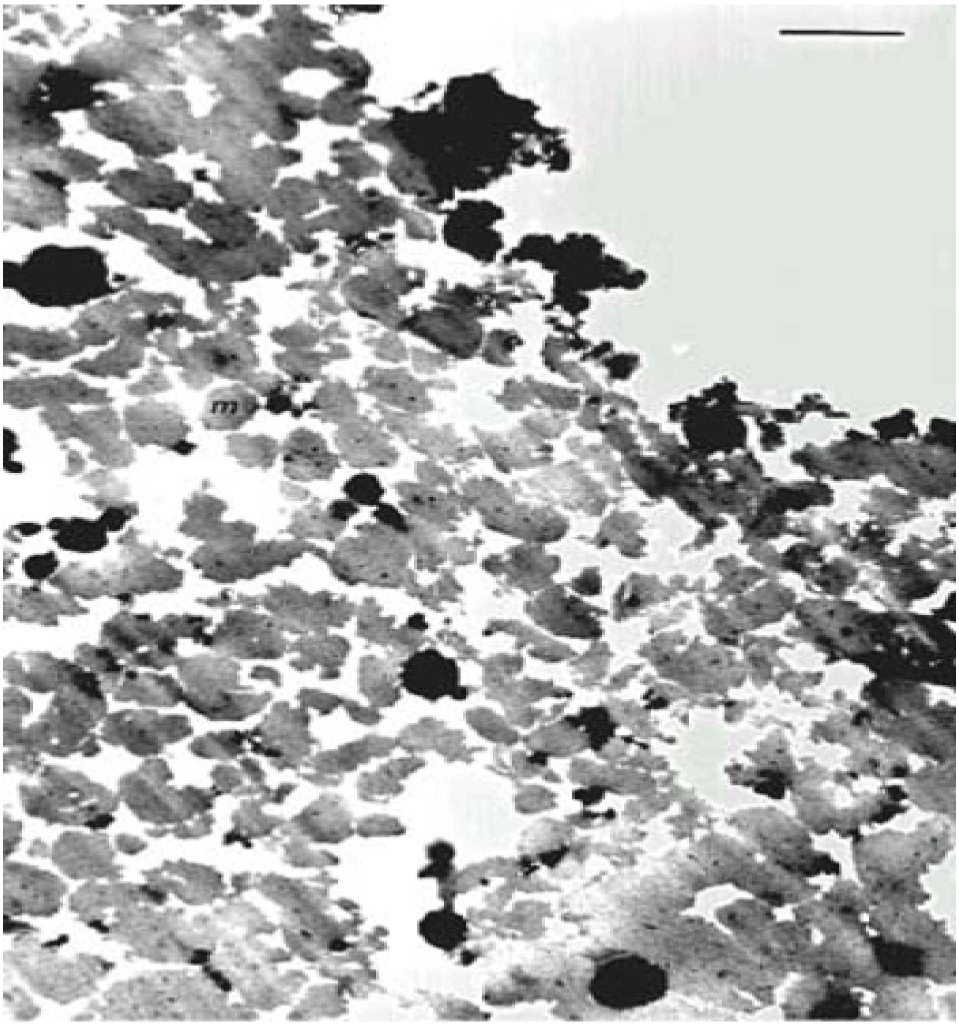

Figure 1. Transmission electron micrograph showing transverse root ultra-thin section of porous degraded hair sample [H083] with infiltrated contaminants distributed throughout the cortex. Scale: 0.7mm
Key: m - macrofibril
Dark circular structures - pigment granules
Dark diffuse stained regions - infiltrated material from the burial environment

FT-Raman spectroscopy (Edwards 1998) was used to confirm the progressive nature of biochemical alteration to hair fibres. Breakdown of the protein structure and conversion of the structural disulphide linkages in cystine to cysteic acid and intermediate states suggested that partial oxidation may occur. The cleavage of disulphide bonds in hair may relate to specific changes due to the decomposition of a body. In an enclosed environment, e.g. a lead coffin environment, these effects may by magnified (Wilson 1999b).

The results of this study highlighted the problems of reliance solely on assessment of sample surface condition. The importance of a multidisciplinary approach is stressed, with use of a combination of suitable test controls. The critical need for assessment of hair degradation in archaeological investigations is now acknowledged (Coghlan 1999).

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